The effect of incorporating carbon nanotubes on impact, transverse strength, hardness, and roughness to high impact denture base material

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ABSTRACT

Background: One of the most common complications of dentures is its ability to fracture, so the aim of this study was to reinforce the high impact denture base with carbon nanotubes in different concentrations to improve the mechanical and physical properties of the denture base.

Materials and methods: Three concentrations of carbon nanotubes was used 0.5%, 1%, 1.5% in a pilot study to see the best values regarding transverse strength, impact, hardness and roughness test, 1 wt% was the best concentration, so new samples for control group and 1wt% carbon nanotubes and the previous tests were of course repeated.

Results: There was a significant increase in impact strength and transverse strength when we add carbon nanotubes in 1wt%, compared to control group where as hardness decrease when adding carbon nanotubes.

Conclusion: the addition of carbon nanotubes improves the physical and mechanical properties.

Key words: Carbon nanotubes, high impact denture base. (J Bagh Coll Dentistry 2015; 27(1):96-99).

INTRODUCTION

Poly methylmethacrylate is one of the most widely used material in prosthetic dentistry, because of its good esthetic, ease of manipulation, low density, low cost and ability to repair, but One of the most common complications of denture base prosthesis is cracking of denture due to its rigidity either from long-term fatigue failure caused by repeated masticatory force or from extra-oral high impact force resulting from accidental dropping of the prosthesis.

Studies have shown that 68% of dentures will break within few years of fabrication [1-4]. So serious efforts to improve the properties of denture base, the goal is to create a material with better mechanical properties; some of these efforts were by incorporating different additives to the polymer like glass fiber, metal wires, long carbon fibers, metal powder fillers, and CNT (Carbon nanotubes).[5]

A wide interest has been generated regarding the use of carbon nanotubes in dentistry, still few reports on the use of CNT as dental material.

CNT are macromolecular form of carbon and considered as a class of nanomaterials, with high potential of biological applications due to their mechanical , physical and chemical properties, CNT has large surface area, ultra-light weight, they are structures of single or multiple sheets of graphene rolled up to form single walled and multiwall CNT [6,7] as in figure (1).

What makes CNT so stable is the strong bond between carbon atoms, in nanotubes the carbon atoms arrange themselves in hexagonal rings, however their only drawback is the high cost and color.[8]

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Nano technology will bring enormous changes into the field of dentistry, however it might pose a risk of misuse, time and human need will determine which of the applications are first realized.[9]

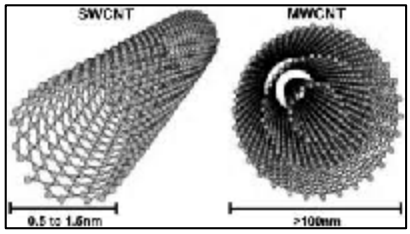

Figure 1: Single wall and multi wall carbon nanotubes

MATERIALS AND METHODS

A pilot study was first undertaken in this study to find out the best concentration of carbon nanotubes when incorporated to high impact denture base material (vertex). Three concentration were selected 0.5wt%, 1.0wt% and 1.5wt% of single wall carbon nanotubes, three samples for each concentration and three samples for each test, were constructed in the dental lab of prosthetic department, collage of dentistry, Baghdad University according to the manufacturing instructions as shown in figure (2).

Figure 2: Samples of pilot study

10 ml of monomer is added to 21mg of powder after mixing, and reaching the dough stage, applying it carefully into the mold which were previously fabricated in the lab following the conventional flasking technique for complete denture with the following dimensions 65× 10×2.5mm (ANSI, ADA specifications No.12) for transverse strength, hardness and roughness, 80×10×4 mm (ISO 179) for the impact test.[10]Then curing for 90 minutes in70^{0}c followed by 30 minutes in 100^0 c, allow for bench cooling; after finishing all the samples, they were re-measured by the digital vernier, the above procedure is for making the control sample, same previous technique is repeated, but by adding carbon nanotubes to 10ml monomer with the aid of the probe sonication apparatus for proper dispersion of nanomaterial to the monomer then quick mixing with 21mg powder to prevent agglomeration. For accurate measurement of powder, carbon nanotubes, electronic balance was used.

For the impact strength, we use impact testing machine, the following equation give us the result in KJ/m^2.

$$\text{Impact strength} = \frac{\text{Energy} \times 103}{D \times B}$$

D=thickness of specimens
B=width of specimen

For testing transverse strength we use the universal testing machines and the final result was obtained from the following equation:

$$\textbf{Transverse Strength} = \frac{\textbf{3x load x span length}}{\textbf{2x width x(thickness)}^2}$$

The profilometer device was used to study the roughness of specimens. For hardness test shore D hardness is suitable device for measuring the acrylic.

Table 1: The mean values of the pilot study

%	Impact strength Kj/m^2	Transverse strength N/mm^2	Hardness No.	Roughness µm
0%	8.25	105	83.3	3.27
0.5%	9.18	134.8	68.3	2.66
1.0%	11.7	160.8	66	2.35
1.5%	10.34	90.7	67	3.93

Based on results obtained from table (1), the 1.0wt% carbon nanotubes had the best values, therefore the decision was to choose this concentration; New samples were prepared, they were divided to two groups first group with no additives (control group), the other group is high impact denture base with 1wt% carbon nanotubes, ten sample for each test were made as previously mentioned.

RESULTS

The statistic analyses give the following results; first table (2) shows the mean, standard deviation, standard error, minimum and maximum of impact strength, transverse strength, roughness and hardness for the control group, whereas table (3) give us the same descriptive values of the same mechanical test but for specimens with1.0wt% CNT.

For the impact strength the mean value was much higher when adding 1.0wt% CNT 11.18Kj/m^2, t-test showed significant difference.

For the transverse strength, the values is also higher 157.3N/mm^2 as seen in table (3) when adding 1.0wt% CNT, compared to the mean values of control samples 107.07 N/mm^2, the t-test give us a highly significant difference as seen on table (4).

Roughness is lower in table (3) when compared to control group in table (2), also the mean value of hardness test showed higher values in table (2) equal to 83.3, compared to table (3) where the mean values equal 66.3.

Table 2: Descriptive of control groups

	Impact strength Kj/ms	Transverse strength N/mm^2	Hardness No.	Roughness µm.
Mean	8.39	107.07	83.22	3.128
SD	0.735	11.702	3.338	0.323
SE	0.234	3.726	1.063	0.103
Min	7.4	90.7	80	2.74
Max	9.5	122	89.1	3.605

Table 3: Surface hardness, roughness, impact strength, transverse strength parameter analysis for 1.0w% CNT

	Impact strength	Transverse strength	Hardness	Roughness
Mean	11.183	157.36	66.58	2.473
SD	2.168	7.093	3.513	0.574
SE	0.690	2.259	1.118	0.182
Min	8.78	148.6	61	1.66
Max	14.8	169.3	72.8	3.09

Table 4: t-test between control group and 1.0wt%CNT

	Impact strength	Transverse strength	Hardness	Roughness
t-test	4.29	11.154	9.871	3.828
p-value	0.002	P<0.01	P<0.01	0.004
Sig	S	HS	HS	HS

***P<0.05 Significant, HS<0.01**

DISCUSSION

This study was designed to investigate the application of carbon nanotubes to high impact denture base resin on some mechanical properties, CNT was chosen because limited studies on their use plus it is known of its high material properties, which are very close to their theoretical limits, like electrical, strength, stiffness and toughness.[11]

The pilot study shows that 1.0wt% CNT had the best values whereas higher wt% of CNT had lower values than control groups, may be due to the inhomogeneous dispersion of CNT causing more agglomerations, the other cause is associated with the interfacial interaction-wetting between polymer and CNT [12]. So the decision was to take the 1.0wt% CNT.

Impact strength

Impact testing machine was used to measure the impact strength, results showed increase values in table (3) when adding 1.0wt% CNT , the highly significant increase in impact strength of the specimen could be due to the inclusion of CNT into the polymer [4], this comes in agreement with Mars and Pienkowski [13] that CNT effectively bridge the cracks, also CNT is strong and stable because, carbon in nanotubes are arranged in hexagonal ring, this lead to a reduction in segmental motion thus increasing the impact strength, results agrees with Luciano et al[14], and Sung et a l[15], that impact strength increase when acrylic resin is reinforced with E-glass fiber, also with Hari et al [16] when adding glass fiber to high impact denture base material.

Transverse strength

The assessment of transverse strength is used in most studies as its loading effect mimics the clinical situation, when denture is in the oral environment receiving various forces.

As seen in table (3) transverse strength is higher than table (2) with highly significant difference, results agree with Zhou [17] by adding carbon nanotubes to poly methylmthacrelate denture base material cause improvement of transverse strength, also Ayad et al [2] showed an increase in transverse strength of high impact resin when reinforced with zirconia, Could be explained by the good dispersion of nano particles which enable them to inter between the chains of polymer and fill the space between them, this will restrict chain movement and will increase strength and rigidity, thus ameliorating the transverse strength [18], also comes in agreement with Wang et al when adding CNT to denture base [12].

Authors also found that loading CNT in polymethyle methycrelate PMMA improve transverse strength, it was suggested that well dispersed CNT is able to reinforce PMMA matrix prior to crack initiation and arresting the early phase of crack propagation [19,20].

Roughness

In the present study we use the profilometer device to estimate the effect of incorporating CNT on surface geometry of specimens, results showed decrease of surface roughness when adding 1.0wt% CNT because CNT are very small in size and well dispersed and since roughness test measure only surfaces, so few particles of CNT on the surface will have no effect, this result agrees with Dahham [20] when modified Zno filler were added to heat cure acrylic.

Hardness

With the aid of shore D hardness tester, the values of hardness decreased in table (3), since

the improvement of properties of CNT and polymer are result of the type of CNT used, the weight added percentage, dispersion, alignment of CNT and polymer matrix [4], so may be one of the above factor did contribute to the result obtained .

Abdulameer [22] also found a decrease in surface hardness when titanium powder is added to acrylic, results also agrees with Ayad et al [2] found that adding zirconia to high impact acrylic resin did not improve the hardness.

The study above showed an improvement of the mechanical properties of high impact denture base when adding CNT, although the material is black in color, so until this esthetic problem is resolved, it may be used in mid line area of complete denture for reinforcement, since it is not a visible place.

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